Novel sutureless telescoping anastomosis revascularization technique of supra-aortic vessels to simplify combined open endovascular procedures in the treatment of aortic arch pathologies

Konstantinos P. Donas, MD,[a] Zoran Rancic, MD,[a] Mario Lachat, MD,[a] Thomas Pfammatter, MD,[b] Thomas Frauenfelder, MD,[b] Frank J. Veith, MD,[c] and **Dieter Mayer, MD,[a]** *Zurich, Switzerland; Cleveland, Ohio; and New York, NY*

Background: **We report our clinical experience with the use of a sutureless telescoping anastomosis, initially described as the VORTEC (Viabahn Open Rebranching TEChnique) revascularization technique, for debranching of supra-aortic vessels.**

Methods: **Between May 2005 and December 2008, 20 patients (15 men) with an aortic arch lesion underwent trans-sternal debranching with sutureless telescoping anastomosis performed with a Viabahn (diameter, 5-8 mm; length, 5-15 cm) or Hemobahn (diameter, 9-13 mm; length, 10-15 cm), followed by endovascular aneurysm repair. Initially, the Viabahn/Hemobahn was sutured to a feeding graft after deployment. Since 2008, the Viabahn/Hemobahn has been deployed within an interposition graft, rendering unnecessary the anastomosis. The underlying aortic pathology was (1) isolated aortic arch aneurysm in 10, (2) aortic arch aneurysm extending to the ascending or descending aorta in 6, (3) floating thrombus within the aortic arch in 1, (4) acute aortic arch dissection in 1, and (5) Crawford II thoracoabdominal aortic aneurysm extending into the aortic arch in 2. Postprocedural duplex ultrasound imaging showed normal flow profiles in all patients. Follow-up included computed tomography angiography at 1, 3, and 6 months postoperatively, and then annually.**

Results: **Overall, 56 supra-aortic vessels in the 20 patients were debranched by sutureless telescoping anastomosis, including the carotid artery in 18, subclavian artery in 13, and left vertebral artery in 1. Technical success was 100%. The mean ischemia time was 3 minutes (range, 1-9 minutes) for the debranching procedure vs 6 minutes (range, 5-16 minutes) for a conventional suture anastomosis. The 30-day mortality rate was 15% (3 if 20); 28.5% (2 of 7) in urgent cases and 7.6% (1 of 12) in elective patients. Three patients (15%) had neurologic deficits after debranching in the conventionally-sutured anastomosis territories. No early (<30 days) occlusion occurred. During a mean follow-up of 14 ± 9 months (range, 1-39 months), one patient with Takayasu disease showed asymptomatic occlusion of a Viabahn implanted into the left common carotid artery. Stenosis in the aortic anastomosis of the bypass graft in another patient was successfully treated by angioplasty and stent placement through the right brachial artery.**

Conclusions: **Sutureless telescoping anastomosis with a Viabahn or a Hemobahn in supra-aortic debranching seems to be a safe and reliable alternative to sutured anastomosis. It enables safe and fast-track revascularizations, especially in anatomically challenging situations, and requires a very short ischemia time. Questions about long-term results and the technique reproducibility must be addressed. (J Vasc Surg 2010;51:836-41.)**

Rapid advances in technology have contributed to improvement of thoracic aortic surgery, which requires deep hypothermic circulatory arrest. However, open repair of thoracic aortic lesions has remarkable morbidity and mortality.[1,2] Debranching of the supra-aortic vessels combined with endovascular aortic repair has also gained increasing acceptance as an alternative to conventional surgery.[3]

Clinic for Cardiovascular Surgery,[a] and Institute for Diagnostic Radiology,[b] University Hospital of Zurich; and Department of Surgery, The Cleveland Clinic and New York University Medical Center.[c]

Competition of interest: none.

Reprint requests: Konstantinos P. Donas, MD, St. Franziscus Hospital, Clinic for Vascular Surgery, Hohenzollernring 72, 48145 Münster, Germany (e-mail: k.donas@gmx.at).

The editors and reviewers of this article have no relevant financial relationships to disclose per the JVS policy that requires reviewers to decline review of any manuscript for which they may have a competition of interest.

0741-5214/$36.00

doi:10.1016/j.jvs.2009.09.054

The aortic arch is geometrically challenging and contains critical branches. Thus, it has been termed the Achilles heel[3] of thoracic endovascular aortic repair (TEVAR). Inadequate landing or fixation in this area can lead to potentially fatal disaster in the worst-case scenario or, at a minimum, an unsatisfactory angiographic result.

To minimize or avoid surgery-related complications, we have introduced a new sutureless telescoping anastomosis technique for trans-sternal supra-aortic debranching in patients with aortic arch pathologies who are intended to be treated by hybrid open endovascular repair. This article presents our short- and midterm clinical experience with this novel debranching technique in 20 patients with aortic arch lesions.

METHODS

Between May 2005 and December 2008, 20 patients (15 men) with aortic arch lesions underwent hybrid open

Table. Patient demographics and underlying aortic pathologies

Variables	*No. (%)*
Risk factors	
Previous myocardial infarction <3 mon	4 (20)
Previous coronary artery bypass/intervention	6 (30)
Cardiac insufficiency (NYHA >I)	4 (20)
Preexisting renal insufficiency	3 (15)
American Society of Anesthesiologists ≤3	20 (100)
Arterial hypertension	20 (100)
Chronic obstructive pulmonary disease	4 (20)
Additional operations	
Renal-visceral debranching	2 (10)
Aortocoronary bypass surgery	4 (20)
Wrapping of the ascending aorta	8 (25)
Aortic arch pathologies	
Aortic arch aneurysm	10 (50)
Elective operation	6 (30)
Urgent operation	4 (20)
Aortic arch aneurysm extending to ascending or descending aorta	6 (30)
Elective operation	5 (25)
Urgent operation	1 (5)
Acute aortic arch dissection	1 (5)
TAAA extending into the aortic arch	2 (10)
Floating thrombus within the aortic arch	1 (5)

NYHA, New York Heart Association; *TAAA,* thoracoabdominal aortic aneurysm.

endovascular treatment and sutureless telescoping anastomosis of supra-aortic vessels at the University Hospital of Zurich. Mean age was 70 ± 7 years (range, 46-86 years). Seven patients required urgent treatment. Patient demographics and underlying aortic pathologies are summarized in the Table.

Surgery. The supra-aortic vessels were approached through a partial or full-length sternotomy. The supra-aortic branches, including the brachiocephalic artery and its branches (right common carotid artery and right subclavian artery), were identified. In most cases, only the anterior wall was dissected. Trans-section of the left brachiocephalic vein was required in nine patients to gain access to the left subclavian artery.

During vascular dissection, an octopus graft was simultaneously prepared ex vivo and tailored to the patient's specific vascular anatomy (Fig 1). The octopus graft was sutured at first to the ascending aorta end-to-side, generally just above the noncoronary sinus, after the application of a side biting clamp. Viabahn or Hemobahn stent grafts (W. L. Gore and Associates, Flagstaff, Ariz) were then introduced and deployed as described below. Finally, the distal end of the octopus graft was anastomosed to the brachiocephalic trunk, and blood flow in the right subclavian artery was re-established.

Doppler ultrasound imaging, when used, was performed after the interruption of the origin of the supra-aortic vessel by ligation or clipping. The left brachiocephalic vein was readapted whenever possible (8 of 9 patients). Finally, a drain was introduced, the pericardium

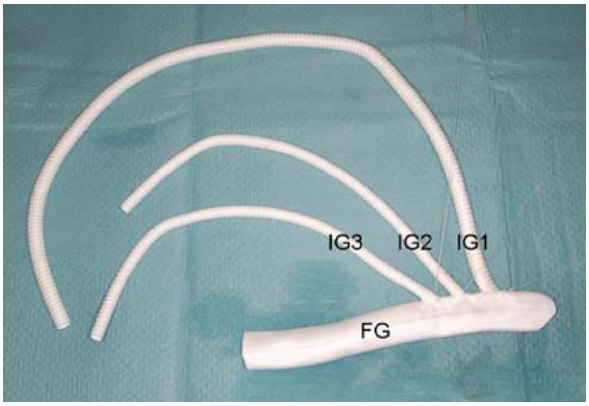

Fig 1. Octopus graft premounted ex vivo. A 16-mm expanded polytetrafluoroethylene graft is intended to bypass the brachiocephalic trunk. Onto this feeding graft *(FG)*, three grafts are sutured as side branches that are intended to bypass the left subclavian artery and both carotid arteries. The Viabahn stent grafts will be introduced inside these interposition grafts (*IG 1-3*). Ideally, the IG will cover the Viabahn completely.

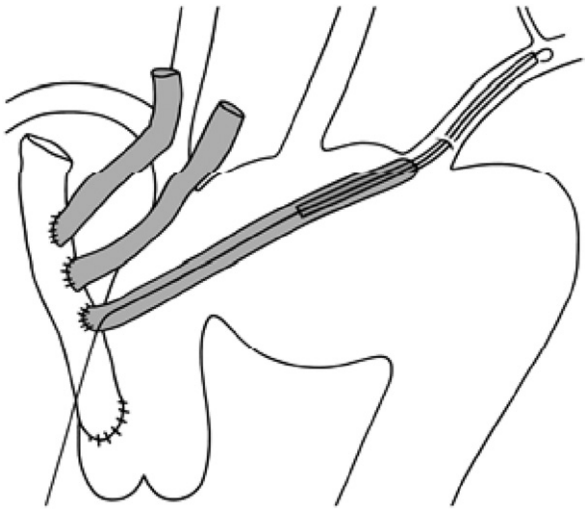

Fig 2. The aortic end-to-side anastomosis of the feeding graft has been performed. The Viabahn is introduced over a guidewire into the interposition graft and the left subclavian artery.

was closed with a xenopericardial membrane (Supple Peri-Guard, Synovis Surgical Innovations, St Paul, Minn), and the sternum was readapted.

Sutureless telescoping anastomosis. After minimal surgical dissection of the origin of the target vessel, the anterior wall was punctured and a guidewire was introduced about 3 to 4 cm into the artery. The needle was removed and the Viabahn or Hemobahn stent graft was introduced over the wire up to 2 cm into the target vessel, depending on the anatomy of the target vessel. Then, the Viabahn device was deployed and finally fully expanded by balloon inflation. Over-sizing or under-sizing was avoided.

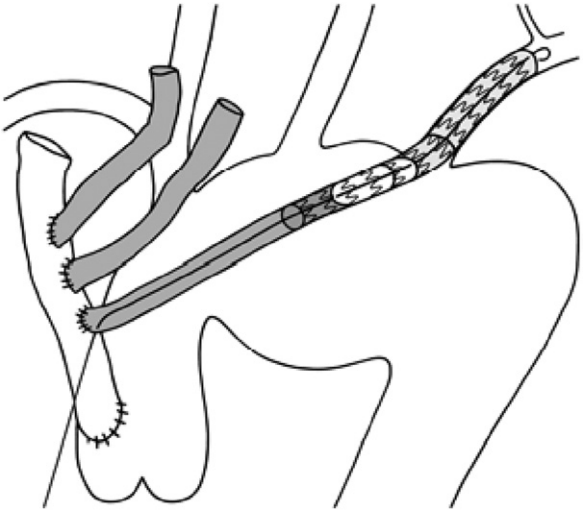

Fig 3. The Viabahn has been deployed into the left subclavian artery, and blood flow has been restored through the interposition graft. Full expansion of the Viabahn is achieved by balloon inflation, which is responsible for several short periods of blood flow interruption.

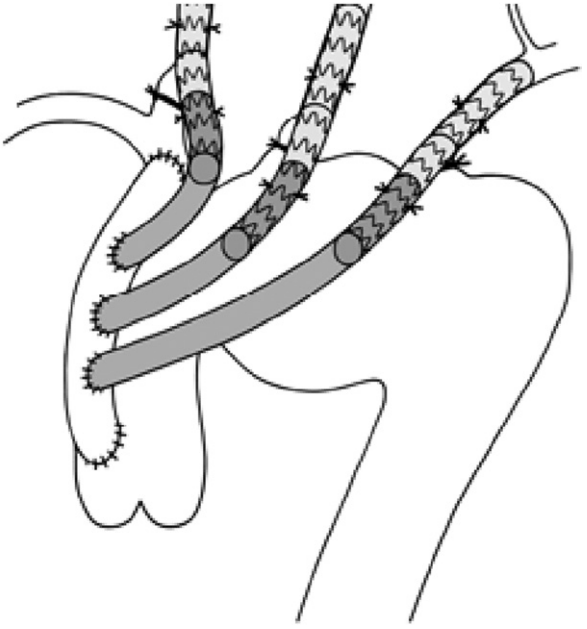

Fig 4. The left subclavian artery and both carotid arteries have been revascularized with the Viabahn technique and the right subclavian artery with a conventional end-to-side running suture on the level of the brachiocephalic trunk. The Viabahn stent grafts have been secured with transparietal 6-0 stitches and the native vessels have been interrupted proximally to the anastomosis by ligation or clip application.

A Viabahn was used for debranching of the supra-aortic vessels with an internal diameter of up to 8 mm (Figs 2, 3 and 4). In vessels with an internal diameter of >8 mm, a Hemobahn, which covers diameters from 9 to 13 mm, was used. The main differences between the Viabahn and the Hemobahn are the diameter of the guiding catheter (0.0035-inch for Viabahn and 0.0025-inch for Hemobahn) and the deployment direction of the device, which is tip to hub for the Viabahn and hub to tip for the Hemobahn.

Initially, in our early experience, the Viabahn and Hemobahn were sutured to a feeding graft after deployment. In our latter experience, since the beginning of 2008, we have deployed the Viabahn or Hemobahn within an interposition graft, which has the advantage of rendering any anastomosis of the Viabahn/Hemobahn unnecessary.[4] That interposition graft was usually chosen 1 mm smaller in internal diameter than the Viabahn/Hemobahn stent grafts.

Special attention was paid to removing the air before blood flow was re-established. Basically, venting is performed in the same manner as with a sutured anastomosis, which is inflow flushing, followed by a backflow flushing maneuver. In all cases, the Viabahn or Hemobahn device was secured with two transmural Prolene 6-0 stitches (Ethicon, Somerville, NJ) on the target artery and on the interposition graft to prevent slipping out (Fig 4). Postprocedural duplex ultrasound imaging of the supra-aortic branches was performed routinely in the intensive care unit.

The decision on where to perform the proximal aortic anastomosis with respect to the site of aortic side clamping is based on preoperative computed tomography scan analysis. When plaques are detected, the exact clamp dimension and position is confirmed by on-table transesophageal echocardiography. The so-called porcelain aorta (circumferential disease) represents the only absolute contraindication to this technique because clamping might induce embolization or aortic dissection, or both.

Endovascular thoracic aortic aneurysm repair. In most patients, retrograde thoracic endovascular aortic aneurysm repair (TEVAR) was performed under local anesthesia at 22 ± 21 days (range, 5-70 days) after the supra-aortic debranching. In eight cases with aortic dissections or severe access tortuosity or aortic kinking, antegrade TEVAR was performed through the ascending aorta immediately after the debranching as a one-step procedure.

TAG stent grafts (W. L. Gore and Associates; diameter, 34 to 40 mm; length, 20 cm) were used in 13 patients, and Evita stent grafts (Jotec, Hechingen, Germany; diameter, 37 to 44 mm; length, 22 cm) were used in the other seven. At least two stent grafts were required in 14 of 20 patients (70%).

The proximal landing zone was zone 0 in 14, zone 1 in two, and zone 2 in four cases. The distal landing zone was the middle descending aorta in 13 patients (70%), extended to the distal aorta in five, and stent grafts extended down to the abdominal aorta in two.

Follow-up. All patients received a thoracoabdominal predischarge CT angiography and were monitored at our outpatient clinic at 3, 6, and 12 months postoperatively,

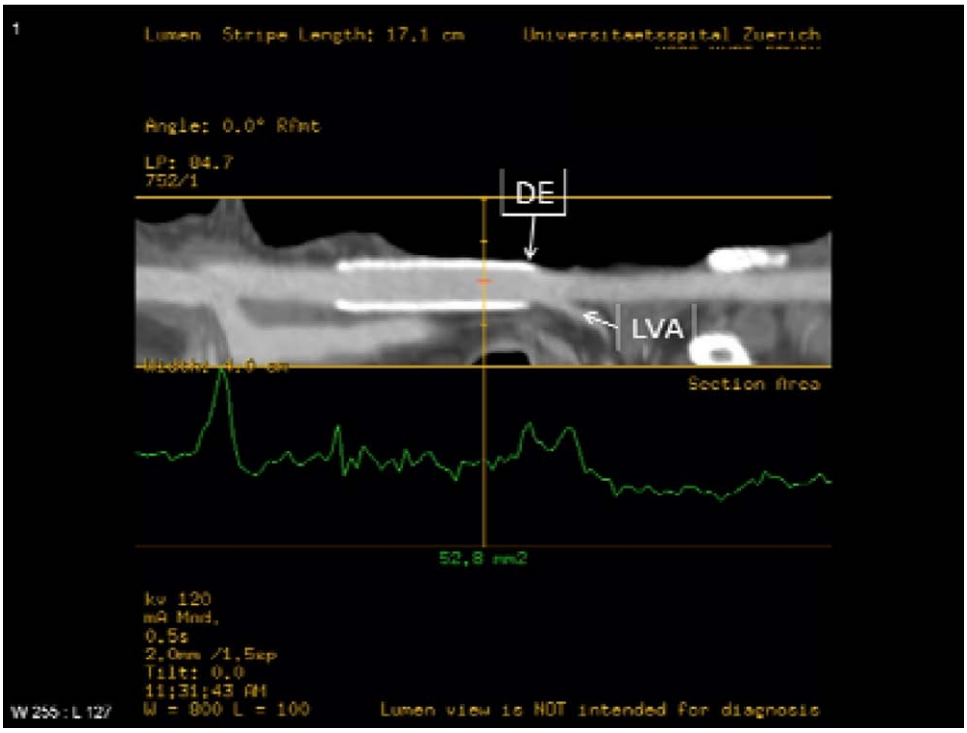

Fig 5. Reconstruction of the follow-up computed tomography angiography shows a Viabahn (internal diameter, 8 mm; length, 5) that was implanted a year earlier into the left subclavian artery. No evidence of stenosis at the distal end (DE) of the Viabahn was recorded. The left vertebral artery *(LVA)* is patent.

and annually thereafter. CT angiography with 2- or 3-dimensional reconstructions of the bypass grafts was routinely performed in all patients (Fig 5).

Anticoagulation. Postoperative medication consisted in intravenous heparinization (full dose) and oral aspirin (100 mg daily). Long-term treatment consisted of oral anticoagulation combined with aspirin (100 mg daily). In patients with contraindications to anticoagulation, a dual antiplatelet regimen combining clopidogrel (75 mg daily) and aspirin (100 mg daily) was given.

Statistical analysis. Descriptive data are presented as mean ± standard deviation and range, if appropriate. Nominal data are given as counts and percentages, and continuous quantitative data were compared with the nonparametric, two-sample, Wilcoxon signed rank test. Statistical significance was set at a value of $P < .05$. The primary patency rate was calculated by crude rates.

RESULTS

The technical success of Viabahn and Hemobahn deployment in the supra-aortic vessels was 100%. In particular, 56 supra-aortic vessels (2.8 vessels per patient) were debranched, 32 by Viabahn/Hemobahn stent grafts (54%). Viabahn/Hemobahn debranching was used in the carotid artery in 18, the subclavian artery in 13, and the left vertebral artery in one. In one case (3%), a Hemobahn slipped out of the interposition graft before it could be fully expanded by balloon dilation. This was corrected by completing an end-to-end anastomosis between the Hemobahn and the interposition graft.

The mean ischemia time was 3 minutes (range, 1-9 minutes) for the sutureless telescoping anastomosis procedure compared with 6 minutes (range, 5-16 minutes) for a sutured anastomosis. There was no early occlusion of any bypass conduit (30-day patency rate, 100%).

Overall the 30-day mortality rate was 15% (3 of 20); in urgent cases it was 28.5% (2 of 7) due to stroke and multiorgan failure, and in elective patients, 7.6% (1 of 13) caused by stroke. Neurologic deficits occurred in three patients (15%) after debranching, in all cases in conventionally-sutured anastomosis territories. Two of the latter patients sustained disabling strokes that were fatal. Another patient sustained paraparesis of the left upper extremity. No neurologic complications occurred during and after the TEVAR procedures. Slight arm swelling was noted in patients where the left innominate vein was ligated intraoperatively or occluded postoperatively. Swelling resolved in all cases before discharge without any particular treatment.

During a mean follow up of 14 ± 9 months (range, 1-39 months), one patient with Takayasu disease showed asymptomatic occlusion of a Viabahn implanted into the left common carotid artery, observing only a stenosed external carotid artery preoperatively. A stenosis developed in the aortic anastomosis of the bypass graft in another patient, which was successfully treated by angioplasty and

Fig 6. Postprocedural computed angiography in an 86-year-old patient with a 7.5-cm isolated arch aneurysm. Viabahn debranching was performed on the left subclavian and both carotid arteries. The feeding graft was implanted into the ascending aorta, just above the sinotubular junction. A pacemaker wire was used to mark the ostium of the feeding graft. The feeding graft lands end-to-side into the brachiocephalic trunk and revascularizes the right subclavian artery.

placement of a self-expanding 7- × 60-mm ev3 Everflex Protege stent (ev3 Inc) through a 6F sheath in the right brachial artery.

DISCUSSION

The sutureless telescoping anastomosis, originally described as VORTEC (Viabahn Open Rebranching TEChnique),[4] allows branch revascularization with only minimal vessel dissection and manipulation. The technique has been shown to be a significant advancement in the treatment of thoracoabdominal and pararenal aortic aneurysms by hybrid procedure and reno-visceral revascularization.[5]

In our experience of 20 supra-aortic debranching procedures with sutureless telescoping anastomosis performed with Viabahn/Hemobahn, this technique also seems to be technically beneficial in the supra-aortic level (Fig 6), showing encouraging results similar to the VORTEC applied on the renal-visceral vessels.[5] The significantly shorter ischemia time of 3 minutes vs 6 minutes in the conventional anastomosis minimizes ischemia-reperfusion injury. No technique-related vessel access complications such as dissection or thrombosis were observed.

In addition, the intrathoracic localization of the Viabahn preserves the exposure of the stent graft to high radial force that is linked to endograft collapse or migration.[6-8] The excellent midterm patency of the revascularized vessels is in contrast with published reports, where Viabahn endografts crossing an articulation present less favorable results.[6-8] The neurologic risk of the Viabahn debranching procedure seems to be low. Three strokes occurred in this series of 20 patients, but none of the strokes were associated with territories revascularized by Viabahn/Hemobahn stents.

Hybrid procedures with previous surgical supra-aortic debranching to allow stent graft implantation in the level of the aortic arch have shown promising results.[9-13] Unfortunately, debranching of the supra-aortic trunks might be challenging because aneurysmal disease often profoundly modifies the arch anatomy, resulting in a cranial, dorsal, or lateral positioning of the supra-aortic vessels. Consecutively, the supra-aortic vessels are often located too deeply or laterally beyond what is reachable through the standard sternotomy.

The mortality rate of untreated thoracic aortic lesions such as aneurysms is >80% at 5 years.[14] Although operative repair greatly alters the natural history of this disease, these aneurysms traditionally require open repair with large two-cavity thoracoabdominal incisions, aortic cross-clamping, and left-heart bypass. Surgery is associated with significant morbidity of 65% to 80% and mortality rates of 10% to 20%.[15]

Another endovascular option to treat aortic arch lesions using the Viabahn stent grafts is the "chimney technique,"[16] whereby the covered stent can be deployed transluminally across the arch or even into the ascending aorta through retrograde catheterization of the left brachial subclavian artery or left common carotid artery, or both, and potentially the right carotid and innominate arteries as well. This is followed by the deployment of a thoracic endograft in the arch, achieving partial or total arch replacement with preservation of antegrade flow into one, two, or all branches.[16] The device interaction and possible graft integrity problems, such as seal disruption and endoleak, are major concerns of this technique, and therefore, long-term evaluation is necessary.

Our suggested technique has some limitations. First, the technique can be hazardous in supra-aortic vessels with severe and extensive atherosclerotic lesions or dissection of the internal carotid artery with extension into the carotid bifurcation due to the risk for distal embolization with devastating neurologic events. We therefore regard the sutureless telescoping anastomosis as a relative contraindication in these situations. In addition, it is probably better to use autologous material in thoracic mycotic aneurysms.

CONCLUSIONS

The sutureless telescoping anastomosis performed with Viabahn and Hemobahn stent grafts allows safe debranching of the supra-aortic vessels, with only short periods of ischemia that minimize cerebral ischemia-reperfusion injury. This technique could be advantageous in older patients and in anatomically challenging situations and is a relevant advancement of hybrid procedures in the treatment of aortic arch pathologies. However, long-term results and reproducibility of our technique from other vascular centers are necessary to establish sutureless telescoping anastomosis with Viabahn/Hemobahn stents in the supra-aortic level.

AUTHOR CONTRIBUTIONS

Conception and design: ML, KD, DM
Analysis and interpretation: KD, ML, ZR, DM
Data collection: KD, ZR, ML, DM
Writing the article: KD, ML
Critical revision of the article: KPD, ZR, ML, TP, TF, FV, DM
Final approval of the article: KD, ZR, ML, TP, TF, FV, DM
Statistical analysis: KD
Obtained funding: Not applicable
Overall responsibility: DM

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Submitted Jul 26, 2009; accepted Sep 19, 2009.

INVITED COMMENTARY

Jeffrey L. Ballard, MD, *Orange, Calif*

This article describes a novel method of performing transsternal debranching of aortic arch branch vessels using a combination of open surgical and endovascular techniques. The authors conclude that in their hands, the technique is safe and minimizes cerebral ischemia-reperfusion injury; however, long-term results and technique reproducibility from other vascular centers are lacking. This commentator also believes that the described telescoping anastomosis technique is likely much more difficult to perform in 3 minutes or less than the article portrays.

In essence, the anterior wall of each target arch branch vessel is dissected and exposed to facilitate subsequent needle puncture and guidewire insertion. Simultaneously, a feeding multilimb graft is attached to a relatively disease-free segment of the ascending aorta. Fig 2 then demonstrates that a guidewire must traverse through the main body of the feeding graft, then through a graft limb, and then into a target aortic arch branch vessel—I would love to see this particular maneuver performed in real-time. Then, 5-cm-long Viabahn or Hemobahn stent grafts (W. L. Gore and Associates, Flagstaff, Ariz) are loaded onto the guidewire and inserted about 2 cm into each target arch branch vessel and deployed. The proximal end of the stent graft is then deployed about 3 cm into the traversed feeding graft limb. Apparently, sutures are required at the stent graft/feeding graft limb interface to prevent stent graft slippage but not at the stent graft/target vessel interface. Finally, the origin of the target aortic arch branch vessel is ligated or clipped. Imaging requirements for the technique, if any, are not well described.

This technique has advantages, as the authors pointed out in their discussion. However, a severely diseased ascending aorta would clearly preclude this type of hybrid procedure, and heavily diseased target arch branch vessels would greatly complicate the approach and likely increase the not insignificant risk of neurologic sequelae.

Like any other novel surgical technique, those who thought about it first consider it to be routine in their practice, while the rest of us sitting on the sidelines wondering would really like to have a bird's-eye view of the authors in action to quell the uneasiness. Fortunately, most vascular surgeons don't sit still very well, and other surgeons will soon report their experience with this seemingly challenging procedure.